NASA-CR-196479

Cooperative Agreement NCC10-0005 July 31, 1994

FINAL REPORT

by

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"RESPONSE OF STRUCTURES AND EQUIPMENTS TO ACOUSTIC EXCITATIONS MODELED AS CONVECTED RANDOM PRESSURE FIELD OR PRESSURE FIELDS WITH BOUNDED UNCERTAIN PARAMETERS"

This final report summarizes analytical investigations which have been performed for predicting the response of linear and nonlinear structures to noise excitations generated by large propulsion power plants of launch vehicles. Detailed results are contained in two technical reports: (1) "Analytical Procedures for Estimating Structural Response to Acoustic Fields Generated by Advanced Launch Systems", June 1992, and (2) "Analytical Procedures for Estimating Structural Response to Acoustic Fields Generated by Advanced Launch Systems - Phase II", July 1994.

Analytical procedures have been developed to take into account incomplete knowledge of boundary conditions of engineering structures due to imperfection in the material and the manufacturing process, or possible damages during previous launches. The incomplete knowledge is characterized by a convex set, and its diagnosis is formulated as a multi-hypothesis discrete decision-making algorithm, with attendant criteria for adaptive termination. Examples are given of rectangular plates and beams supported by transverse and rotational springs of

(NASA-CR-196479) RESPONSE OF STRUCTURES AND EQUIPMENTS TO ACOUSTIC EXCITATIONS MODELED AS CONVECTED RANDOM PRESSURE FIELD OR PRESSURE FIELDS WITH BOUNDED UNCERTAIN PARAMETERS Final Report (Florida Atlantic Univ.) 3 p

N95-70115

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Z9/39 0019821

uncertain spring constants, modeling possible defects or damages along the boundary. Bolotin's dynamic edge effect method is applied to determine the natural frequencies. Analytical procedures are devised to identify the damage in the boundary conditions and the resulting changes in the natural frequencies of a structure, using a finite element formulation.

Techniques have been developed to analyze the free and forced vibrations of a multi-span beam, which is a commonly used structural form near a launch site. Motions at periodic supports are determined using the concept of wave propagation in periodic structures of Brillouin. The analysis is extended to the vibration of a two-dimensional grillage of beams, assuming that the grillage is constrained at each intersection of two beams by a rigid transverse support and two elastic rotational springs in two orthogonal directions. The elastic springs on each row are identical; thus, the entire grillage forms a two-dimensional periodic pattern. The four boundary edges of the grillage are assumed to be either simply supported or clamped. Again the wave propagation approach is used for the analysis.

As an illustration for practical application, the random vibration of a typical weather protection system for space shuttles at a launch site has been studied. It is shown that the Timoshenko-beam model captures the essential structural behaviors of such a system, and that the use of the conventional Bernoulli-Euler beam theory may result in an error of about 50% in the computed mean-square value of the bending moments. The large error can result in under-design of the structure, which may have dangerous consequences.

New methods have been developed for the analysis of nonlinear structures subjected to noise excitations. Although there exist known methods to obtain exact mean-square responses of non-linear systems, they are based on the assumption of highly idealized random excitations.

Therefore, approximate methods are the practical means to deal with complex continuous structures under realistic random loadings. In the present study, a new energy-based stochastic linearization method has been developed, with applications to discrete systems, as well as continuous structures, such as elastic beams. The simplest cases, for which exact solutions are obtainable, are first considered, and the results are compared with those obtained from the conventional and the new stochastic linearization techniques. It is shown that the new stochastic linearization technique is more accurate than the conventional one. The nonlinear response of a beam, for which an exact solution is unavailable, has also been investigated. The results are compared with those of Monte Carlo simulations. Again, superior performance of the new approximation technique has been demonstrated.

It is shown that, when both damping and the restoring force are nonlinear, the accuracy can be improved further by using a partial stochastic linearization method, in which only the non-linear damping in the original system is replaced by a linear viscous damping, while the non-linear restoring force remains unchanged. The replacement is based on the criterion that the same average energy is consumed by the nonlinear damping force in the original system and its linear counterpart.

The possibilities of future research in this general subject area are diverse. General commercially available computer softwares for engineering structures do not include programs for rigorous random vibration or convex analyses. Development of comprehensive finite element programs to incorporate random vibration and convex analyses into general purpose codes is therefore necessary, especially for application to large-scale structures. It is hoped that these tasks can be addressed in phase III.